A THESIS.

The Relative Value of Certain Illinois Soils For the Production of Wheat.

By

Melville A. Scovell
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A man cannot live without food. If he is placed in a position where he is unable to obtain food, he starves and dies. Moreover he must have such elements in his food as enter into and compose the different parts of his body. He cannot live on fat alone, for there is no nitrogen to enter into the composition of his muscles; no no lime or phosphorus to build up the framework of his body. He may eat only of fat for a time The oleagenous matter may give rotundity to his form. It may produce the necessary heat required; it may help to regulate the temperature; it may lubricate the mechanisms of the body, but it cannot long sustain it. The bony frame-work soon crumbles, the muscles relax, and he dies for want

of proper food.

So a plant in order to survive must have food. The food must contain all the elements entering in the composition of the plant. A plant deprived of any of these elements soon dwindles and dies.

If a man cannot obtain his food in one place he seeks another. If he is thirsty he goes to the well and drinks. When he becomes hungry, he leaves his work and walks sometimes miles to obtain his food.

It is not so with a plant. It has not the power of locomotion. Wherever it germinates there it remains. It can only send its roots a little ways into the ground; its branches but a little distance into the atmosphere to obtain its food.

If the soil from which it sprung and the atmosphere in which it is, cannot furnish in quality as well as quantity its food, it must certainly die.

How important it is then that seed which we wish to germinate and grow, should be placed in such a soil as can furnish the proper and necessary amount & food.

Man must not only be supplied with the necessary elements & his food; but they must be in such a condition as that he may convert them into food. Man can find in the earth the elements necessary for his food, but they do not subserve him in this condition, because he is not able to convert them as they are into the substances which make up his body.

It is so with plants. The soil must not only contain the elements of its food, but also the elements in condition to be taken up as food.

Although man must have food in order to live, yet he may die with plenty of food. Other things are to be taken into consideration besides that of food.

Likewise a plant may not flourish in a soil which furnishes it plenty of food; other agencies have their affect upon the life of a plant.

The first of these may be mentioned that of <u>climatic influence</u>

The soils of Illinois may contain the food required for a tropical plant, but the climate is too severe for this delicate plant. Even plants which grow lux-

uriously one year in a certain soil are a total failure the next year, because perhaps the soil was too wet, or too dry at the time of planting or during growth; perhaps because the weather was too hot or too cold.

Next, the physical condition of the soils have a great influence on the growth of vegetation. Some plants grow in compact soils, others in the soils which are loose. Even the same soil differs in its physical condition at different periods, owing partly to the care taken of it and partly to the climatic influence on it. Soils therefore of the same plant food, but differing in physical condition will grow the same plants with quite different results.

It is very well known that the prairie soils of Illinois do not produce winter wheat as abundantly as those of the woodlands. Most of the woodlands are said to be good wheat producing soils, while the prairie lands are not. The Mississippi bottoms are especially good wheat growing lands and are call everlasting wheat soils.

The object of this thesis was to ascertain if possible, by chemical analysis wheather the prairie soils were deficient in the quality or amount, or both, of food necessary for wheat.

For this purpose, six soils, which were sent to the University, by Hon. J. S. Johnson, from near Erbille Illinois were analyzed. Mr. Johnson superintended the gathering of these and

gave the following data:

The soils were collected at the depths of five inches. They have never been manured. The grass has never been taken from the prairie soil. They are numbered, 1. 2. 3. 4. 5. and 6.

No. 1 is from the Mississippi second bottom everlasting wheat soil. It has been in cultivation 114 years. For the last 17 years it has been in wheat.

No 2. This soil is from timber land adjoining the prairie. It has been in cultivation six years: four wheat crops taken off and two of corn.

No 3 is a prairie soil which has been in cultivation 28 years 6 in wheat; 8 in corn; 1 in oats; 5 in meadow; 3 in pasture; 3 in corn; now in meadow.

No. 4 has been in cultivation

42 years. It is prairie land, and a crop has been taken off every year.

No. 5. Soil taken from an adjoining field ten rods from prairie. It has been in cultivation 31 years: 5 in wheat 23 in corn; 1 in oats; 2 in corn.

No 6 This soil is virgin prairie.

Each of these specimens as sent consisted of about ten pounds.

The method of Analysis was as follows:

The air dried soil was thoroughly mixed to insure uniformity. About 500 grams were then passed through a sieve of 50 meshes to the inch. The sifted portion was then kept at a temperature of 100°C. for three days to completely dry it.

Of this portion 40 grams were taken for the estimation of

of the soluble alkalies, and 40 grams for General estimation

The 40 grams for the general estimation was treated with 120 C.C. of hydrochloric acid of 1.15 sp. Gr. and the mixture allowed to stand at the ordinary temperature for 48 hours. It was then filtered and thoroughly washed and the washings added to the filtrate

This divided the soil into two portions: Soluble and Insoluble The object of this was to ascertain 1st. the amount of each soil now serviceable to the crops and second, to find out the durability of the soils. Hydrochloric acid was taken to separate the two portions, because it is believed that this reagent dissolves about the same amount of a soil that a

plant is capable of absorbing. As it is now known that plants not only absorb the soluble portion of soils, but also have the property of taking undissolved portions. As however plants can only take up certain portions of the insoluble soils, it would not do to analyze the soils without making a dividing line somewhere between the soluble & insoluble portions of the soil

A. Soluble Portion.

The hydrochloric acid filtrate was concentrated, a few drops of nitric acid added to oxidize any ferrous iron present, and then brought strictly to dryness on a water bath in a porcelain dish; the residue moistened with strong hydrochloric acid, and allowed to digest for half an hour, then

treated with water and filtered and completely washed. The residue ignited and weighed showed the amount of silica soluble in 2 grams of the soil.

Copper.– The filtrate obtained from the silicious matter was saturated with hydrosulphuric acid, to precipitate any copper present. The precipitate was collected upon a filter, then washed as far as possible from the filter into a porcelain dish; the filter reduced to ash and added to the contents of the dish. The whole was then evaporated on a water bath; the residue dissolved, transferred into a beaker, and treated with an excess of H_2S to precipitate the copper. The mixture was boiled and then filtered. The dried precipitate separated as far as pos-

sible from the filter. The filter reduced to ash in a porcelain crucible, and cooled; then a drop of nitric acid was added to dissolve any copper reduced and the excess of acid expelled by heat. The precipitate was then added to the ash and the whole ignited and weighed.

The filtrate obtained from the sulphide of copper precipitate was boiled to expel any hydrosulphuric acid, cooled, sodium carbonate added until the precipitate formed by the last drop of this reagent did not dissolve by agitation, then a drop of acetic acid added, and the mixture boiled. To the boiling solution an excess of a hot solution of sodium acetate was added to precipitate the iron, alumina and phosphonic acid. The

precipitate was allowed to subside, the clear liquid decanted and the precipitate washed first in the beaker and then thereon on the filter and washed with hot water. The filtrate and the washings were reserved for the estimation of manganese, lime, and magnesia.

The precipitate was dissolved in nitric acid, and the solution diluted to exactly 250 C.C.

Of this solution there was taken for the estimation of:

Phosphoric acid 50 C.C.
Iron - - - - - 25 C.C.
Alumina - - - 25 C.C.

Phosphoric acid—. The 50 C.C. measured out for this purpose was concentrated on a sand bath to about 5 C.C. and then the phosphoric acid precipitated by a nitric acid solution of molybdate of ammonium (1:35), and the mix

ture allowed to stand in a warm place for twelve hours. The yellow precipitate was then collected upon a filter and washed with water containing molybdate of ammonium. The filtrate was tested with molybdate of ammonium to insure complete precipitation of the phosphoric acid. The precipitate was dissolved on the filter with diluted ammonia, and the beaker washed out, in which the phosphoric acid had been precipitated, with ammoniacal water, and the washings passed through the filter. The ammoniacal solution was then heated to the boiling temperature, the phosphoric acid precipitated by a magnesia mixture (NH_4Cl $MgSO_4$, NH_4HO, and the whole dissolved in a litre of water), and allowed to stand 24 hours. The

precipitate was then collected on a filter and washed with water containing ammonia, then dried, ignited and weighed as pyrophosphate of magnesia and estimated as P_2O_5.

Iron – The 25 C.C. measured out for the estimation of the iron was treated with pure sulphuric acid in a porcelain dish, and the mixture evaporated until the chlorine was entirely expelled. The contents of the dish were then transferred to a pint flask containing a strip of platinum. Pure sulphuric acid and water was then added to the contents of the flask, and a piece of pure zinc suspended in the liquid by means of a platinum wire. The flask was then so stoppered, as above, as to exclude the exit of the hydrogen without admitting air. This is best done by stop-

pering the flask with a rubber stopper, through which passes a glass tube, connected with a rubber tube in which a small slit is cut lengthwise of the tube and which is stoppered at the other end.

The object of treating the iron in this manner was to reduce the iron to protoxide, so as to estimate by a standard solution of permanganate of potassium.

The reaction was allowed to go on for half an hour, the zinc was then removed and washed with hot water, and the washings added to the contents of the flask. More pure sulphuric acid was then added and finally a solution of permanganate of potassium of known strength, by means of a burette, until the last drop occasioned

a coloration in the liquid. The amount of permanganate of potassium it took to oxidize the iron was noted and the iron determined from this data.

The reaction which takes place by adding a solution of permanganate of potassium to a solution of a ferrous salt is as follows:

$10\,FeSO_4 + 2\,KMnO_4 + 8\,H_2SO_4 = 5\,Fe_2(SO_4)_3 + 2MnSO_4 + K_2SO_4 + 8\,H_2O$.

Alumnia – The free acid in the 25 C.C. measured for the estimation of alumina was exactly neutralized with sodium carbonate, and then a solution of hyposulphite of soda (1-5) added until the liquid became colorless, a drop of Na_2CO_3 was then added and finally an excess of hyposulphite of soda, and the mixture boiled for four hours. It was filtered while hot

and washed. The residue was ignited and weighed.

Manganese– The filtrate reserved from the precipitate caused by sodium acetate was treated with two or three drops of bromine and then boiled. The precipitate was collected on a filter, ignited, weighed and estimated as Mn_3O_4.

Lime– The foregoing filtrate was evaporated to about 100 C.C. then a slight excess of ammonia added and the lime precipitated while the solution was still hot, with ammonium oxalate. The mixture was allowed to stand 24 hours. The lime was collected upon a filter, dried and removed as much as possible from the filter, the filter reduced to ash in a porcelain crucible, a drop of ammonium carbonate added to change back

any oxide to carbonate, gently ignited to expel excess of ammonium carbonate and then the remainder of the precipitate was transposed to the crucible & the crucible heated to dull redness until the $C_2H_2O_4$ was converted into carbonate. It was then cooled, weighed, and estimated. Enough ~~was combined~~ estimated as CaO to combine with the P_2O_5, and the remainder is estimated as $CaCO_3$.

Magnesia – The filtrate from the calcium oxalate was concentrated cooled, NH_4HO added in excess and the magnesia precipitated by hydrogen sodium phosphate. The mixture was allowed to stand 24 hours, then collected on a filter washed with ammoniacal water, dried, ignited, and weighed as pyrophosphate of magnesia. The percent of magnesia was found

from this weight by the following proportions:

$Mg_2P_2O_7 : 2MgO :: Wt.\ of\ Mg_2P_2O_7 : X$

Wt of soil taken : X :: 100 : Y = % MgO.

Sulphuric Acid. – The 40 grams weighed out for the estimation of the alkalies was digested in 120 C.C. of hydrochloric acid of 1.15 sp.gr. for 48 hours, then diluted somewhat and filtered, the iron oxidized, and the solution brought to dryness on a water-bath in a porcelain dish, water added and any residue separated by filtration. The filtrate was boiled and just enough barium chloride added to precipitate the sulphuric acid. The mixture was allowed to stand twelve hours. Then the $BaSO_4$ collected upon a filter, ignited and weighed.

Alkalies – The filtrate from the sulphuric acid precipitate was treat-

ed with ammonium carbonate in excess and the mixture boiled when the precipitate had subsided it was filtered, and washed. The filtrate and washings were brought to dryness in a platinum dish on a water bath, then ignited to expel the ammonia salts, the residue treated a concentrated solution of hydrogene oxalate, again brought to dryness and ignited to dull redness to convert the alkaline earths to carbonates. The contents of the dish was then treated with water and filtered The solution which ~~now~~ then contains the alkalies, was acidulated with hydrochloric acid and brought to dryness in a platinum dish of known weight, gently ignited, cooled, and weight. This weight will represent the amount of potassa and soda as chlorides, in the soluble portion of 40 grams

of soil They were separated from each other as follows:
The weighed chlorides were dissolved in dilute hydrochloric acid, transfered to a small beaker, an excess of platinic chloride added, and the whole brought to dryness on a water bath: the residue agitated with a mixture of alcohol and water, and finally filtered on a weighed filter, washed with alcohol and water, dried at 100°C. and the residue weighed. The potassa was weighed here as $2KCl.PtCl_4$, and to find the per cent of this alkali the following proportions are necessary:

$2KCl.PtCl_4 : 2KCl :: \text{Weight of } 2KCl.PtCl_4 : y = \text{wt of } KCl$

$2KCl : K_2O :: y : a = \text{wt of } K_2O$

$40 \text{ grams} : a :: 100 : z = \%\ K_2O$

To find the soda, the weight of KCl was subtracted from the sum of the alkalies, and the difference represented the weight

of NaCl, then by the following, the per cent was found:

$2NaCl : Na_2O :: W\ NaCl : x$

$40 : x :: 100 : y = \%\ Na_2O$

Organic Matter and water - One gram of the soil dried at 100°C. was ignited in a platinum crucible until the organic matter was consumed, then weighed and the loss by weight represented the total organic matter in one gram of soil; subtracting from this amount the organic matter found in the insoluble portion, the difference represented the soluble organic matter.

B. Insoluble Portion.

The portion insoluble in hydrochloric acid, while still upon the filter was dried at 100°C. for several days. It was then taken from the filter as far as practicable, the filter ignited and the ash added to the

rest. The whole was now weighed and the total amount of insoluble matter ascertained.

Of the dried insoluble matter there was taken for:

General estimation ——— 2 grms.
alkalies and Organic matter 2 grms.

This last portion was thoroughly ground in an agate morter.

Silicic acid. - The two grams weighed out for general estimation were fused with 4 grams each of carbonate of soda and carbonate of potassa in a platinum crucible; while still hot the platinum crucible was set in water in a porcelain dish and thus allowed to cool. The object of dipping the crucible in water, while still hot, was so as that the fused mass after cooling might be removed easily from the crucible. After cooling the fused mass was digested

with water in a porcelain dish on a water bath, and then an excess of hydrochloric acid was added and the whole brought completely to dryness, the residue moistened with hydrochloric acid, and finally water added and filtered and thoroughly washed. The residue, ignited and weighed represented the amount of silica in this portion.

The filtrate was diluted to exactly 200 C.C.

Of this amount there was taken for the estimation of:

Phosphoric acid &c. ——— 160 C.C.

Al_2O_3 ---------- 40 C.C.

Both solutions were neutralized with sodium carbonate, and then the alumnia, phosphoric acid and any iron precipitated by sodium acetate in the usual manner. The filtrates were

united and reserved for the estimation of manganese, lime and magnesia.

Alumina. The precipitate obtained from the 400 C.C. was ignited and weighed. The ignited residue represented the alumina and phosphoric acid present.

Phosphoric Acid. The precipitate of alumina and phosphoric acid from the 160 C.C. of solution was dissolved in hot nitric acid and then brought nearly to dryness, then treated with an excess of molybdate of ammonium solution (1-35), and the mixture allowed to stand 24 hours in a warm place. The yellow phosphoric acid precipitate was then collected on a filter, washed with ammonium molybdate solution diluted with water, dissolved in dilute ammonia, the ammoniacal solution heated to the

boiling temperature, a magnesia mixture added, the mixture allowed to stand 24 hours, the precipitate collected upon a filter, washed with ammoniacal water, dried, ignited, and weighed as pyrophosphate of magnesia

Mn_3O_4 - The solution reserved for the estimation of manganese, lime, and magnesia was treated with a few drops of bromine, the solution boiled, and the manganese collected upon a filter, ignited and weighed.

Lime - The above filtrate was concentrated, ammonia added and the lime precipitated by ammonium oxalate, allowed to stand 12 hours, then filtered, and the calcium estimated in the usual manner.

Magnesia - The filtrate from which the lime has been taken

was concentrated, and the magnesia precipitated by hydrogen di sodium phosphate after standing twelve hours the precipitate was collected upon a filter, washed with ammoniacal water, dried ignited and weighed as magnesium pyrophosphate.

Organic Matter. The two grms of the insoluble portion weighed out for the estimation of the organic matter and alkalies, were ignited in a platinum crucible until the organic matter was consumed, then cooled and weighed. The loss by weight represents the amount of organic matter in two grams of the insoluble portion.

Alkalies. The foregoing residue was intimately mixed in an agate morter with two grams of ammonium chloride, after which six parts of pure Calcium

carbonate were gradually added and the whole thoroughly mixed. The mixture was transferred to a long platinum crucible, the crucible gently heated until the ammonium salts were expelled; the crucible was then covered, and the heat gradually increased until the portion of the crucible containing the mixture was heated to cherry redness, at which temperature it was kept for one hour, when the crucible was allowed to cool. The crucible should not be heated too hot as some of the alkalies might volatilize

The sintered mass was transferred to a mortar, moistened with water, and pulverized, washed in a beaker, and the crucible and its cover washed and the washings added to the contents of the beaker. The mix-

ture was then gently boiled on a water bath for about half an hour, then filtered; the filtrate was treated with ammonium carbonate and concentrated to about 25 C.C. when a little more carbonate of ammonium and ammonia were added, to precipitate the last traces of lime, then filtered and the filtrate transferred to a platinum dish, and brought to dryness on a water bath. The ammoniacal salts were then expelled by heat; the residue dissolved in hydrochloric acid and again brought to dryness, heated to very dull redness, allowed to cool, and weighed.

The alkalies were then separated from each other by the method employed in the soluble portion.

The table shows the Composition of the six soils examined:

Composition of Soils Examined.

	No 1.			No 2.			No 3.		
Soluble in Hydrochloric acid	6.09			5.27			4.76		
Organic matter & water		1.1690			1.2800			1.3300	
Silicic acid		0.0632			0.0710			0.0660	
Sesquioxide of iron		1.5150			1.6870			1.2375	
Alumina		2.0600			1.3050			1.0811	
Phosphate of calcium		0.5080			0.3540			0.3543	
Carbonate of calcium		0.4250			0.1103			0.3342	
Carbonate of magnesia		0.0880			0.1137			0.0320	
Potash		0.0433			0.0550			0.0315	
Soda		0.0116			0.0165			0.0085	
Sulphuric acid		0.1335			0.2440	5.24		0.1845	
Soluble matter found			6.0196			5.24			4.6635
Insoluble in Hydrochloric acid	93.9100			94.63			95.24		
Organic matter		0.5189			0.5800			0.5430	
Silicic acid		77.5647			76.3022			77.5825	
Alumina with trace of iron		9.9535			9.3589			9.1336	
Lime		0.6495			0.2941			0.9147	
Magnesia		0.3383			0.6095			0.3768	
Potash		1.6847			2.2550			1.1191	
Soda		1.1244			0.8942			0.6686	
Phosphoric acid		0.1913			0.2080			0.1637	
Insoluble matter found			94.0254			94.5119			94.501
Totals	100	100.0450	100.0450	100	99.75	99.75	100	99.16	99.16

Composition of Soils Examined.

	No 4.			No 5.			No 6.		
Soluble in Hydrochloric	6.02			5.32			6.00		
Organic matter & water.		1.7800			1.5300			2.4300	
Silicic acid		0.1130			0.0770			0.0730	
Sesquioxide of iron		1.5750			1.1250			1.1250	
Alumina		1.3500			1.8350			1.5700	
Phosphate of calcium		0.3281			0.5114			0.3490	
Carbonate of calcium		0.4457			0.0735			0.0405	
Carbonate of magnesia		0.0220			0.0230			0.0280	
Potash		0.0421			0.0289			0.0257	
Soda		0.0045			0.0076			0.0100	
Sulphuric acid		0.1537			0.3419			0.3687	
Soluble matter found			5.5171			5.3536			6.0199
Insoluble in Hydrochloric	93.95			94.68			94.0000		
Organic matter		4.3607			4.4162			5.6115	
Silicic Acid		75.9359			77.2683			75.0872	
Alumina with trace iron		9.8632			10.1751			10.4340	
Lime		0.5395			0.3467			0.3290	
Magnesia		0.4398			0.4179			0.4945	
Potash		1.5752			1.1912			1.1453	
Soda		1.0655			0.6571			0.8142	
Phosphoric acid		0.1315			0.1476			0.1165	
Insoluble matter found.			93.9113			94.6231			94.0355
Totals	100.00	99.73	99.73	100.00	99.98	99.98	100.00	100.05	100.05

The most important constituents of soils are; the alkalies phosphoric acid, lime, magnesia, iron, and sulphuric acid.

As the soluble portion is supposed to represent the present available food, it is only necessary it is only necessary to compare the results in this division, in order to ascertain whether a Chemical analysis show why the woodlands of Illinois are wheat producing soils, while the prairie lands are not.

As the table shows the soils do not differ materially in their chemical composition. The result therefore is negative

Comparing the amount of phosphoric acid in each soil, we find that while the "Everlasting wheat soil" (No 1) contains a large amount of this constituent, the next wheat soil does not con-

tain as much as one of the prairie soils, which is not wheat producing (No 6). and contains the same quantity as the prairie soil No. 3. The conclusion must be then that the soluble phosphates in the soils do not, in themselves alone determine the relative value as wheat producing soils.

Comparing the iron, we find here also that no conclusion can be reached on the subject from this source, for soil No 4 contains more iron than soil No 1, and nearly as much as soil No. 2.

Again comparing the alkalies the difference in the amount of these constituents in the different soils does not warrant the statement that the prairie soils need to be supplied with these elements in order to produce wheat: for if soil No 1. which produces wheat

from year to year, without manuring, contains .0433 per cent of potash, it is evident that it has abundant supply of this element. Then why would not soil No. 4, containing almost the same amount produce wheat as well? The roots of the wheat could easily spread a little further, and delve a little deeper in the soil, in order to obtain the proper amount of this element if necessary.

So in comparing all the other constituents, each to each, the differences in the amount of the constituents are so small that the conclusion must be, that if soils No 1 and 2. have food enough and of proper quality for the production of wheat, then the prairie soils also are as rich in wheat food, and if wheat refuses to grow and produce upon them, the causes must be

other than that of food. Hence to solve this problem we must look to climatic influences or to the physical condition of the soils. If prairie soils adjoining timber lands refuse to produce as much wheat, and the climate is the same, then the physical condition of the soil must be investigated. If the soils of are of different natures physically, then cultivation, and the rains will have different effects upon them. Their natural drainage may be different which will show a difference in their physical nature.

The ~~fictile~~ soils of Illinois are rich in plant food, If their physical nature is or can be made ~~so~~ by drainage or otherwise, such as the plants require which we wish to raise upon them, and the climate is suitable for such

plants, then there is no reason why they should not do well.

In conclusion, the question may be asked "Why is it that the prairie lands of Illinois are good wheat soils for the first two or three years, and then are not? It is evidently owing to the change in their physical condition, Cultivation has more to do with it, perhaps, than we are aware. If this subject could be investigated, and remedied, then the prairie lands of Illinois would produce as much wheat, and of as good a quality as their neighboring woodlands.

M. A. Scovell